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Vehicle Noise Emission Levels in Kentucky

by

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16. Abstract

The objectives of this study were to update individual vehicle noise data taken in previous years in Kentucky and to determine reference mean energy emission levels for Kentucky vehicles for use in the SNAP 1 noise prediction procedure.

Comparison of Kentucky and nationwide emission levels showed a close agreement for medium and heavy trucks; however, automobile noise levels in Kentucky were higher than nationwide levels. An analysis of emission levels of the various vehicle types showed that a fourth category, light trucks, may need to be added. The Kentucky emission levels were input into SNAP 1 in place of the nationwide levels, but the nationwide values gave closer overall results when compared to measured values. Therefore, it was recommended that the use of nationwide emission levels be continued in the SNAP 1 program until such time as results showing closer agreement between measured and predicted values using the nationwide levels can be explained. It was also recommended that the equations relating emission levels and speed for the four categories of vehicles (automobile, light trucks, medium trucks, heavy trucks) be adopted as representative of emission levels for vehicles in Kentucky.

Noise levels of automobiles and trucks were found to have decreased over the past several years.

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Introduction

Traffic noise has reached high levels in some areas and is considered a major pollutant of the environment. A survey of noise levels generated by individual automobiles and trucks operating on Kentucky highways was made in 1973 (1). One objective of this study was to determine how noise emission levels have changed.

Noise emission levels for different vehicle types were needed for input into the traffic-noise prediction procedure adopted for use in Kentucky, January 1, 1980 (2). The procedure specifies that reference vehicle noise emission levels be determined by each state to replace nationwide levels given in the prediction methodology. Reference mean energy emission levels were determined as a function of speed for vehicles in Kentucky. The new equations were input into the prediction procedure to determine the effect on its accuracy.

Procedure

The procedure recommended for measuring vehicle noise has been outlined in previous reports (3, 4). The basic methodology given in those reports was used.

The noise level and speed were recorded for each vehicle. The noise level was measured in dBA. The prediction procedure used in Kentucky specifies three vehicle categories (5): automobiles, medium trucks, and heavy trucks. The automobile category also includes light trucks with four tires. Medium trucks are defined as vehicles having two axles and six tires. Heavy trucks have three or more axles. Vehicle categories were further subdivided as given in Table 1. Automobiles were classified as compact, medium, and full size based on visual observations. Motorcycles were considered separately.

Data were taken at 17 sites chosen to represent a wide range of vehicle speeds and vehicle types. All sites had to meet certain criteria. The site had to be in a level, open space free of large reflecting surfaces; ground cover had to be short grass; vehicles could not be accelerating or decelerating; and background sound level had to be at least 10 dBA lower than the vehicle noise. Data were not taken when the wind would have interfered with the measurements.

The microphone was placed 50 feet (15 m) from the centerline of the nearest traffic lane, and measurements were taken for vehicles in that lane. The microphone was mounted approximately 5 feet (1.5 m) above the pavement and at least 3.5 feet (1.1 m) above ground level. The highest sound level of the passing vehicle was recorded as the vehicle emission level (Lo). This level had to be unaffected by noise of other vehicles. Vehicle type, noise level, and speed were recorded for each vehicle.

A large sample was collected. A statistical regression analysis program (SPSS for OS/360, Version M, Release 7.2) was used to determine reference mean energy emissions. The equation was:

$$Lo = a + b \log (speed) \quad (1)$$

in which Lo = peak sound level (dBA).

The objective was to determine mean energy emission levels to replace the nationwide reference levels given in Figure 1 (3). The data used to determine nationwide emission levels for trucks are given in reference 6. The vertical axis of Figure 1 represents the mean energy emission level $(\overline{Lo})_E$ for the vehicle category. This is the average of the energies (not maximum sound levels) of each event. To arrive at the mean energy level, an adjustment must be added to the peak sound level (Lo) determined by the

Table 1. Vehicle Categories and Types.

GENERAL CATEGORY	TYPE	CODE
AUTOMOBILE (A)	AUTO-COMPACT	AC
	AUTO-MEDIUM SIZE	AM
	AUTO-FULL SIZE	AF
	AUTO-GENERAL	AG
	SINGLE UNIT, TWO-AXLE, FOUR-TIRE TRUCK	SU2A4T
MEDIUM TRUCK (MT)	SINGLE UNIT, TWO-AXLE, SIX-TIRE	SU2A6T
	BUS, TWO-AXLE	B2
HEAVY TRUCK (HT)	SINGLE UNIT, THREE-AXLE	SU3A
	SINGLE UNIT, FOUR-AXLE	SU4A
	COMBINATION, THREE-AXLE	C3A
	COMBINATION, FOUR-AXLE	C4A
	COMBINATION, FIVE-AXLE	C5A
	COMBINATION, SIX-AXLE	C6A
	BUS, THREE-AXLE	B3
MOTORCYCLE	MOTORCYCLE	MC

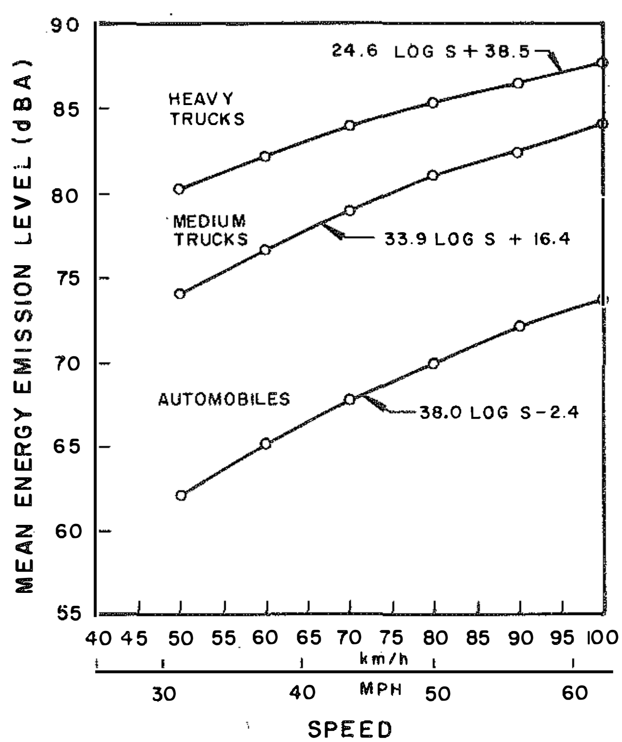

Figure 1. National reference mean energy emission levels as a function of speed.

regression analysis. The adjustment factor is 0.115 times the standard error of the estimate from the regression equation (3). Using this procedure, mean energy emission levels were determined as a function of speed. The new equations were input into the SNAP 1 prediction procedure. The effect of changing the reference emission levels on the accuracy of SNAP 1 was determined.

In addition to the three vehicle categories specified in the prediction procedure, emission levels were determined for 15 vehicle types cited in Table 1. Comparisons were also made between noise levels found in this study and noise levels of vehicles in past years.

An octave-band analysis was made for one vehicle type representing each of the three categories. Data were taken for automobiles, single-unit two-axle six-tire (SU2A6T) trucks, and combination five-axle (C5A) trucks. Data were taken and analyzed separately for an interstate and urban location to represent low and high vehicle speeds.

Results

NOISE LEVELS OF MAJOR VEHICLE TYPES

Noise and speed data were taken of 10,128 vehicles. A summary of the number of measurements taken for each vehicle type is given in Table 2. A summary of the data by location is given in the APPENDIX.

Summaries of noise and speed data for the three vehicle categories are cited in Tables 3 through 5. The summary tables give, for each speed range, the number of vehicle measurements, the average noise level and speed, the standard deviations of the noise levels and speeds, and the range of noise levels measured. The lowest speed was 20 mph (32.2 km/h) and the highest was 69 mph (111.0 km/h). The medium truck noise level was 6.9 dBA higher than the automobile noise level. The average noise level for heavy trucks was 4.8 dBA higher than for medium trucks. The increase in average noise levels from the lowest to the highest speeds was 11.0 dBA for automobiles, 11.7 dBA for medium trucks, and 11.9 dBA for heavy trucks. The standard deviation varied from 2.3 to 4.6 dBA. There were large variations in noise levels at the different speeds. Noise levels for specific vehicle types traveling at a given speed varied significantly.

A regression analysis relating vehicle noise and speed was performed for

Table 2. Summary of Number of Vehicles Measured.

CATEGORY	TYPE	NUMBER OF VEHICLES
AUTOMOBILE	AC	1389
	AM	2019
	AF	2447
	AG	79
	SU2A4T	1757
	TOTAL	7691
MEDIUM TRUCK	SU2A6T	705
	B2	59
	TOTAL	764
HEAVY TRUCK	SU3A	208
	SU4A	57
	C3A	76
	C4A	161
	C5A	1059
	C6A	27
	B3	8
	TOTAL	1596
MOTORCYCLE	MC	77
ALL		10128

Table 3. Summary of Automobile Noise Data By Speed.

SPEED RANGE (MPH*)	NUMBER OF VEHICLES	NOISE LEVEL ANALYSIS (DBA)			SPEED ANALYSIS (MPH)	
		AVERAGE	STANDARD DEVIATION	RANGE	AVERAGE	STANDARD DEVIATION
20-29	1253	63.1	3.5	50-76	25.8	2.5
30-39	1620	65.4	3.8	55-84	34.1	2.8
40-49	1889	70.2	3.6	58-85	45.1	2.8
50-59	2503	72.6	2.9	57-89	53.9	2.7
60-69	426	74.1	2.3	67-82	62.0	2.1

* 1MPH = 1.609 KM/H

Table 4. Summary of Medium Truck Noise Data By Speed.

SPEED RANGE (MPH*)	NUMBER OF VEHICLES	NOISE LEVEL ANALYSIS (DBA)			SPEED ANALYSIS (MPH)	
		AVERAGE	STANDARD DEVIATION	RANGE	AVERAGE	STANDARD DEVIATION
20-29	136	69.2	4.6	58-83	24.8	2.7
30-39	172	72.8	4.3	62-85	33.4	2.8
40-49	229	77.3	3.9	68-88	45.2	2.7
50-59	219	79.6	3.3	69-89	53.5	2.5
60-69	3	80.9	4.5	73-87	63.4	2.6

* 1MPH = 1.609 KM/H

Table 5. Summary of Heavy Truck Noise Data By Speed.

SPEED RANGE (MPH*)	NUMBER OF VEHICLES	NOISE LEVEL ANALYSIS (DBA)			SPEED ANALYSIS (MPH)	
		AVERAGE	STANDARD DEVIATION	RANGE	AVERAGE	STANDARD DEVIATION
20-29	118	73.3	4.5	62-91	24.2	2.8
30-39	141	79.2	4.4	63-93	35.0	2.8
40-49	425	82.3	3.4	71-95	45.2	2.8
50-59	803	83.9	3.1	67-98	54.1	2.7
60-69	109	85.2	3.9	71-98	62.1	2.3

* 1MPH = 1.609 KM/H

each vehicle category. Results are summarized in Table 6. The noise level was taken as a linear function of the log of the speed. This form has been used by others (6). As shown in Table 6, the multiple correlation coefficient (R^2) ranged from 0.43 to 0.57 and indicated that about one-half of the variation could be explained by speed. The standard error of the estimate was between three and four.

The analysis yielded an equation for the predicted peak dBA of a vehicle passing by at 50 feet (15 m). The reference mean $(\bar{L}o)_E$ includes a factor of 0.115 times the standard error of the estimate (σ_o). This factor is based on the assumption that the reference mean energy emission level has a normal distribution.

Plots of the reference means as a function of speed for the three vehicle categories are given in Figure 2. A

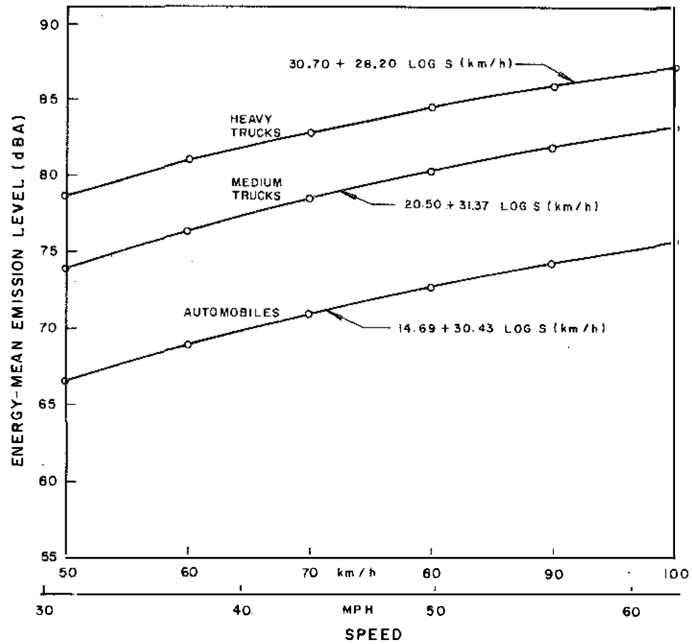

Figure 2. Reference mean energy emission levels for Kentucky vehicles as a function of speed (three vehicle categories).

Table 6. Equations Relating Speed and Noise Emission Levels for Major Vehicle Types.

VEHICLE TYPE	SPEED UNITS	$\bar{L}_o$ *	R^2 **	σ_o***	$(\bar{L}_o)_E$ ****
AUTOMOBILES	KM/H	13.41 + 30.43 LOG S	.57	3.34	14.69 + 30.43 LOG S
	MPH	19.69 + 30.43 LOG S			20.97 + 30.43 LOG S
MEDIUM TRUCKS	KM/H	18.76 + 31.37 LOG S	.51	3.89	20.50 + 31.37 LOG S
	MPH	25.24 + 31.37 LOG S			26.98 + 31.37 LOG S
HEAVY TRUCKS	KM/H	29.34 + 28.20 LOG S	.43	3.44	30.70 + 28.20 LOG S
	MPH	35.16 + 28.20 LOG S			36.52 + 28.20 LOG S

* $\bar{L}_o$ -PREDICTED PEAK DBA LEVEL OF A VEHICLE PASSING BY AT 50 FEET (15 M) AT A GIVEN SPEED

** R^2 -COEFFICIENT OF DETERMINATION

*** σ_o -STANDARD ERROR OF THE ESTIMATE

****$(\bar{L}_o)_E$ -REFERENCE ENERGY MEAN EMISSION LEVEL ((L) = L + 0.115) comparison of national and mean energy levels in Kentucky is given in Figure 3. A large difference occurred among automobiles: emission levels were higher in Kentucky and ranged from about 4 dBA higher at 50 km/h (31 mph) to 2 dBA at 100 km/h (62 mph). Emission levels for medium trucks showed the closest agreement -- levels in Kentucky were slightly below national levels, and the maximum difference was 1 dBA at 100 km/h (62 mph). Emission levels for heavy trucks were also slightly lower in Kentucky and ranged from 0.6 to 1.7 dBA (the largest difference at 50 km/h (31 mph)).

NOISE EMISSION LEVELS FOR VEHICLES OF VARIOUS TYPES

The numbers of measurements obtained are cited in Table 2. The objective of this phase of the study was to determine if the current assignment of particular types of vehicles into the three categories was proper. Motorcycles were the only vehicle type which did not fit a designated category. The data, therefore, would indicate the category to which motorcycles should be assigned.

A summary of the data for the various types of vehicles averaged by speed range is given in Table 7. There were only

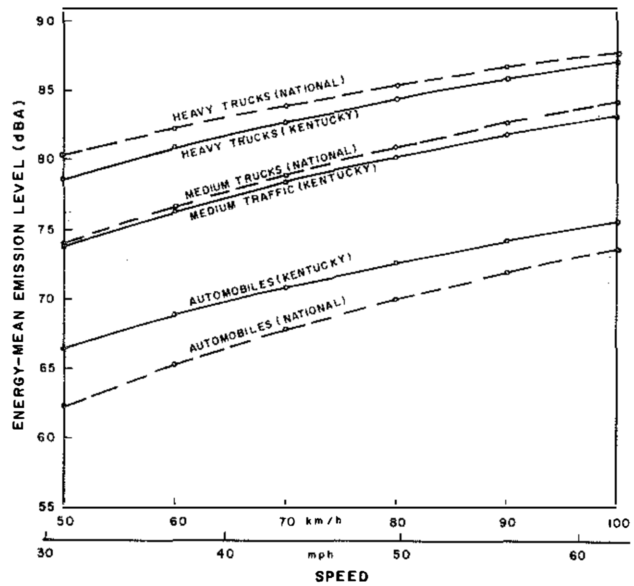

Figure 3. Comparison of national and Kentucky mean energy emission levels.

Table 7. Summary of Noise Data For Various Vehicle Types and Speeds.

VEHICLE TYPE		SPEED RANGE (MPH) (KM/H) 20-29 (32.2-46.7)	30-39 (48.3-62.8)	40-49 (64.4-78.8)	50-59 (80.4-94.9)	60-69 (96.5-111.0)
AC	SAMPLE SIZE	266	418	304	351	50
	NOISE LEVEL	62.6*	64.4	69.3	71.7	73.2
AM	SAMPLE SIZE	379	423	496	627	94
	NOISE LEVEL	62.9	64.6	69.4	72.0	74.0
AF	SAMPLE SIZE	323	442	545	924	213
	NOISE LEVEL	62.8	64.9	69.6	72.3	73.8
SU2A4T	SAMPLE SIZE	285	335	520	549	68
	NOISE LEVEL	64.1	67.9	72.1	74.4	76.1
SU2A6T	SAMPLE SIZE	116	154	213	214	8
	NOISE LEVEL	69.3	73.0	77.3	79.5	80.9
B2	SAMPLE SIZE	20	18	16	5	0
	NOISE LEVEL	68.7	71.2	77.1	81.4	NA
SU3A	SAMPLE SIZE	33	39	68	65	3
	NOISE LEVEL	75.2	79.3	81.4	83.0	90.0
SU4A	SAMPLE SIZE	4	19	17	17	0
	NOISE LEVEL	76.5	80.5	81.5	81.6	NA
C3A	SAMPLE SIZE	9	15	28	24	0
	NOISE LEVEL	73.1	76.4	79.8	83.0	NA
C4A	SAMPLE SIZE	26	9	49	73	4
	NOISE LEVEL	72.0	78.3	80.9	82.6	81.2
C5A	SAMPLE SIZE	44	55	251	608	101
	NOISE LEVEL	72.6	79.2	83.1	84.2	85.4
C6A	SAMPLE SIZE	2	4	10	11	0
	NOISE LEVEL	68.5	84.0	83.6	86.4	NA
MC	SAMPLE SIZE	19	18	15	19	6
	NOISE LEVEL	69.1	71.9	74.1	75.7	78.0

* AVERAGE NOISE LEVEL (DBA)

slight differences (less than 1 dBA) among average noise levels of compact, mid-size, and full-size automobiles. Noise levels were slightly higher for large automobiles. The other vehicle type included in the automobile category was the single unit two-axle four-tire (SU2A4T) truck. The average noise level for this vehicle was over 2 dBA higher than for automobiles. However, the noise level for the SU2A4T truck was much less than for medium trucks. The average noise levels for the single unit two-axle six-tire (SU2A6T) truck were about 5 dBA above the level of the SU2A4T truck. A limited number of measurements of the two-axle bus (B2) showed it properly belonged in the medium truck category. A significant difference was found when the single unit, three-axle (SU3A) truck was compared to the medium truck. The noise levels of SU3A trucks were slightly above some of the combination trucks. Trucks having three or more axles were generally comparable and logically form a separate category. Noise levels of motorcycles were between the automobile and heavy truck categories.

The same regression analysis used for the three major vehicle categories was also used for each of the various vehicle types. A summary of the results of this analysis is given in Table 8. Eleven of the 15 vehicle types are listed. Plots comparing the mean energy levels for the various vehicles are shown in Figure 4. Except for motorcycles and SU2A4T trucks, the vehicles generally fell in the three major categories: automobiles, medium trucks, and heavy trucks. The noise

Table 8. Equations Relating Speed and Noise Emission Levels for Various Vehicle Types.

VEHICLE TYPE	SPEED UNIT	$\bar{L}_o$	R^2	σ_o	$(\bar{L}_o)_E$
AC	KM/H	13.85 + 29.69 LOG S	.57	3.21	15.03 + 29.69 LOG S
	MPH	19.98 + 29.69 LOG S			21.16 + 29.69 LOG S
AM	KM/H	15.34 + 29.10 LOG S	.59	3.15	16.48 + 29.10 LOG S
	MPH	21.35 + 29.10 LOG S			22.49 + 29.10 LOG S
AF	KM/H	11.70 + 31.11 LOG S	.61	3.00	12.74 + 31.11 LOG S
	MPH	18.12 + 31.11 LOG S			19.16 + 31.11 LOG S
SU2A4T	KM/H	14.11 + 31.08 LOG S	.56	3.41	15.45 + 31.08 LOG S
	MPH	20.52 + 31.08 LOG S			21.86 + 31.08 LOG S
SU2A6T	KM/H	18.99 + 31.26 LOG S	.49	3.90	20.74 + 31.26 LOG S
	MPH	25.45 + 31.26 LOG S			27.20 + 31.26 LOG S
B2	KM/H	20.03 + 30.36 LOG S	.55	3.75	21.65 + 30.36 LOG S
	MPH	26.30 + 30.36 LOG S			27.92 + 30.36 LOG S
SU3A	KM/H	37.23 + 23.83 LOG S	.39	3.71	38.81 + 23.83 LOG S
	MPH	42.15 + 23.83 LOG S			43.73 + 23.83 LOG S
C3A	KM/H	26.66 + 28.82 LOG S	.47	3.46	28.04 + 28.82 LOG S
	MPH	32.61 + 28.82 LOG S			33.99 + 28.82 LOG S
C4A	KM/H	28.34 + 28.05 LOG S	.55	3.38	29.65 + 28.05 LOG S
	MPH	34.14 + 28.05 LOG S			35.45 + 28.05 LOG S
C5A	KM/H	30.00 + 28.01 LOG S	.37	3.26	31.22 + 28.01 LOG S
	MPH	35.79 + 28.01 LOG S			37.01 + 28.01 LOG S
MC	KM/H	37.92 + 19.55 LOG S	.32	4.17	39.92 + 19.55 LOG S
	MPH	41.96 + 19.55 LOG S			43.96 + 19.55 LOG S
A*	KM/H	13.07 + 30.32 LOG S	.60	3.11	14.18 + 30.32 LOG S
	MPH	19.33 + 30.32 LOG S			20.44 + 30.32 LOG S

*(EXCLUDING SU2A4T)

levels of SU2A4T trucks were slightly over 2 dBA higher than those for automobiles. However, given the three categories, SU2A4T trucks should be included with automobiles rather than medium trucks. The SU2A4T category includes pickup trucks, vans, and other trucks with four tires. The SNAP 1 program allows four vehicle categories. Either motorcycles or SU2A4T trucks could be placed in the fourth category. The low volume of motorcycles in Kentucky may not warrant establishing a separate category. Motorcycles, therefore, should be included with medium trucks. An additional category termed light trucks (SU2A4T trucks) may be established using the relationship shown in Table 8. This would require a new relationship between noise level and speed for automobiles, excluding SU2A4T trucks. Such a relationship is shown in Table 8. A previous report stated that the noise levels predicted by SNAP 1, using national reference mean energy emission levels, were close to measured levels (2). Another such comparison using mean energy levels in Kentucky would show whether the existing categories are adequate or if a fourth category for light trucks should be added.

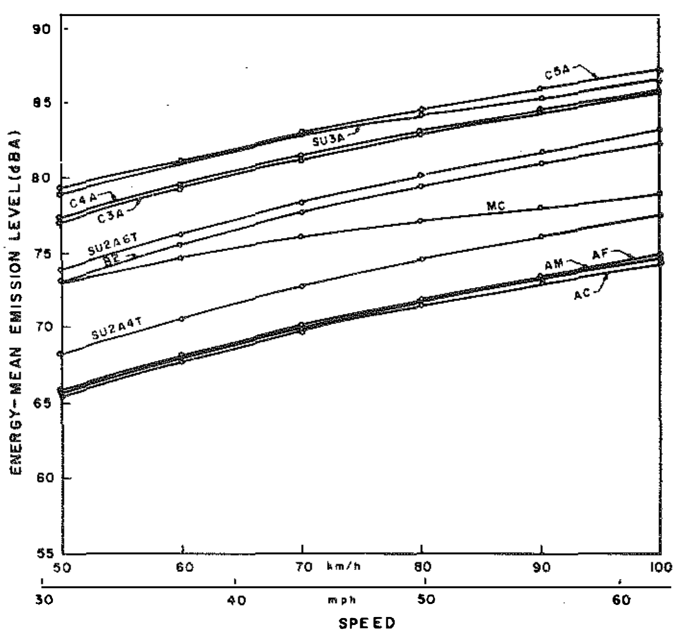

Figure 4. Comparison of mean energy emission levels for various vehicle types.

MODIFICATION OF PREDICTION PROCEDURE

Using the equations shown in Table 6, the effect of substituting Kentucky's mean energy emission levels for the nationwide levels on the accuracy of the SNAP 1 procedure was determined. The data used in the previous evaluation of SNAP 1 (2) were used. A summary of the comparison of measured, SNAP 1 predicted, and revised SNAP 1 predicted L10 and Leq levels is given in Table 9. The revised SNAP 1 predictions used the Kentucky values for mean energy emission levels. For each of the six sites representing a range in traffic volumes and speeds, the data were summarized by distances to the centerline of the roadway. A total of 472 10-minute recordings were used. To obtain the average measured and SNAP 1 predicted L10 and Leq levels at each distance, an average of the individual 10-minute recordings was calculated. These values were available from the previous study (2). However, the revised SNAP 1 predicted values (using Kentucky vehicle noise levels) were calculated using the average hourly values shown in Table 9 so that one calculation was made for each distance.

The comparison of Kentucky and national mean energy emission levels shown in Figure 3 showed a significant difference in the automobile category. Kentucky levels were considerably higher. Therefore, when automobiles dominate the traffic stream and are the major source of traffic noise, the use of Kentucky's emission levels should result in an increase in the predicted noise level. The data in Table 9 show this was the case. At Site 1, where there was a very low truck volume, the revised SNAP 1 predictions were 2 to 3 dBA higher than the original SNAP 1 predictions. At Site 3, where there was a high volume of trucks, the revised and original SNAP 1 predicted values were basically the same. There was an overall tendency for the revised SNAP 1 values to be higher. The original SNAP 1 predictions were generally more accurate than the revised values.

The values for each distance at each site were averaged, and the differences between measured and predicted values were calculated (Table 10). As shown in the

Table 9. Comparison of Measured and Predicted Noise Levels Using Kentucky Reference Mean Energy Emission Levels.

LOCATION	SITE NUMBER	SPEED LIMIT (MPH) (KM/H)	DISTANCE*** (FEET)(M)	NUMBER OF 10 MINUTE MEASUREMENTS	AVERAGE HOURLY VOLUME				AVERAGE L_{10} (DBA)			AVERAGE L_{eq} (DBA)		
					A	MT	HT	TOTAL	MEASURED*	SNAP 1*	REVISED SNAP 1**	MEASURED*	SNAP 1*	REVISED SNAP 1 **
SOUTH LIMESTONE STREET,	1	40	73 (22)	31	2021	42	6	2069	67.0	67.7	70.6	64.9	66.0	68.5
US 27, LEXINGTON		(64)	123 (37)	28	2079	37	5	2121	63.8	64.3	67.0	61.6	62.4	65.1
			223 (68)	29	1861	41	5	1907	60.3	60.2	62.5	57.7	58.1	60.7
			423 (129)	14	2478	33	5	2516	58.4	56.2	58.8	56.3	54.6	57.4
HARRODSBURG ROAD,	2	55	86 (26)	38	452	25	16	493	68.4	66.5	67.3	65.1	65.9	65.8
US 68, LEXINGTON		(88)	136 (41)	25	476	28	20	524	64.1	64.4	64.9	61.2	63.3	63.1
			236 (72)	27	514	29	13	556	58.8	60.6	61.4	56.4	58.5	59.1
INTERSTATE 75	3	55	86 (26)	10	951	62	215	1228	79.6	76.8	76.7	76.2	73.2	73.0
		(88)	111 (34)	26	1169	71	268	1508	77.6	75.7	75.8	74.1	72.1	72.2
			136 (41)	12	1004	63	227	1294	76.6	74.0	73.8	72.8	70.4	70.2
			186 (57)	10	1279	68	213	1560	71.6	71.6	71.6	68.3	68.1	68.2
			336 (102)	37	1228	75	276	1579	68.8	68.1	67.9	65.3	65.1	65.0
INTERSTATE 264	4	55	84 (25)	38	3695	156	181	4032	77.0	78.1	78.4	74.4	75.0	75.3
		(88)	134 (40)	31	3601	153	186	3940	73.7	75.0	75.3	70.8	71.7	72.3
			234 (71)	30	3813	140	173	4126	68.3	70.8	71.1	65.5	67.8	68.4
WINCHESTER ROAD,	5	55	56 (17)	15	488	24	10	522	68.8	68.1	70.2	65.6	66.6	68.3
US 60, LEXINGTON		(88)	106 (32)	17	454	25	11	490	64.8	64.7	65.8	61.2	62.4	64.0
			206 (63)	12	487	20	8	515	61.3	59.7	61.0	57.5	57.6	59.0
DIXIE HIGHWAY,	6	40	92 (28)	15	2703	128	72	2903	72.7	71.8	72.5	69.9	68.7	69.8
US 31W, LOUISVILLE		(64)	142 (43)	15	2718	123	60	2901	67.8	68.6	69.4	64.7	65.6	66.7
			242 (74)	12	2812	130	58	3000	63.2	64.8	65.8	60.9	61.9	63.3

* AVERAGE OF INDIVIDUAL 10-MINUTE RECORDINGS

** ONE CALCULATION BASED ON AVERAGE VOLUME AT EACH DISTANCE

*** DISTANCE FROM CENTERLINE OF PAVEMENT

previous study, there was very close agreement between measured and SNAP 1 predicted values with an overall difference for all sites of 0.1 dBA for L10 and 0.5 dBA for Leq. The overall difference increased to 0.9 dBA for L10 and 1.5 dBA for Leq when the revised SNAP 1 procedure was used. There was a particularly large difference in measured and predicted values at Site 1. This resulted from the higher automobile emission levels for Kentucky vehicles and automobiles dominated the traffic stream at Site 1.

The vehicle emission levels determined in this study are representative of Kentucky vehicles rather than nationwide as given in the SNAP 1 procedure. Therefore, substituting Kentucky values should improve the accuracy of noise predictions. A close agreement between measured and SNAP 1 predictions was found before (2), and it was thought that the use of emission levels based on Kentucky vehicles may improve the accuracy even more. However, L10 values in Table 9 show an absolute difference between measured and predicted noise levels of 1.3 using SNAP 1 predictions and 1.7 using the revised SNAP 1 predictions. The fact that the SNAP 1 procedure was developed using the nationwide emission levels may account for closer agreement using the national values.

Also shown in Table 10 are results obtained when four, rather than three, categories of vehicle types were used.

Table 10. Comparison of Average Measured and Predicted Noise Levels By Site.

SITE NO.	AVERAGE L_{10} (DBA)				AVERAGE L_{eq} (DBA)				DIFFERENCE FROM MEASURED (DBA)					
			REVISED SNAP 1				REVISED SNAP 1		L_{10}			L_{eq}		
										REVISED SNAP 1			REVISED SNAP 1	
	MEASURED	SNAP 1	THREE VEHICLE TYPES	FOUR VEHICLE TYPES	MEASURED	SNAP 1	THREE VEHICLE TYPES	FOUR VEHICLE TYPES	SNAP 1	THREE VEHICLE TYPES	FOUR VEHICLE TYPES	SNAP 1	THREE VEHICLE TYPES	FOUR VEHICLE TYPES
1	62.4	62.1	64.7	65.0	60.1	60.3	62.9	62.8	0.3	2.3	2.6	0.2	2.8	2.7
2	63.8	63.8	64.5	64.8	60.9	62.6	62.7	62.7	0	0.7	1.0	1.7	1.8	1.8
3	74.8	73.2	73.2	73.2	71.3	69.8	69.7	69.7	1.6	1.6	1.6	1.5	1.6	1.6
4	73.0	74.6	74.9	75.1	70.2	71.5	72.0	71.9	1.6	1.9	2.1	1.3	1.8	1.7
5	65.0	64.2	65.7	65.8	61.4	62.2	63.8	63.8	0.8	0.7	0.8	0.8	2.4	2.4
6	67.9	68.4	69.2	69.6	65.2	65.4	66.6	66.5	0.5	1.3	1.7	0.2	1.4	1.3
ALL	67.8	67.7	68.7	68.9	64.8	65.3	66.3	66.2	0.1	0.9	1.1	0.5	1.5	1.4

The fourth category, termed light trucks, was the SU2A4T category. The equation shown in Table 8 was used for this category. Also, the revised automobile equation shown in Table 8, excluding SU2A4T vehicles, was used for automobiles. The medium and heavy truck categories were not changed. Plots of the reference mean energy emission levels as a function of speed for the four categories of vehicles are given in Figure 5. Volume counts during data collection classified the vehicles into the three categories so that the light truck category could not be isolated. However, vehicle classification counts are taken regularly, and these counts were used to estimate the percentage of light trucks. At Sites 1, 3, 4, and 6, light trucks were estimated to constitute 17 percent of the automobile category. At Sites 2 and 5, light trucks were estimated to account for 23 percent of the automobile category. A limited number of additional counts at these locations found these estimates to be very close.

The results obtained using four categories of vehicles were very similar to those for three categories. The L10 predictions were actually slightly worse using four rather than three vehicle categories; the Leq predictions were slightly better. The original SNAP 1 values were still better, particularly where automobiles dominated the traffic stream noise.

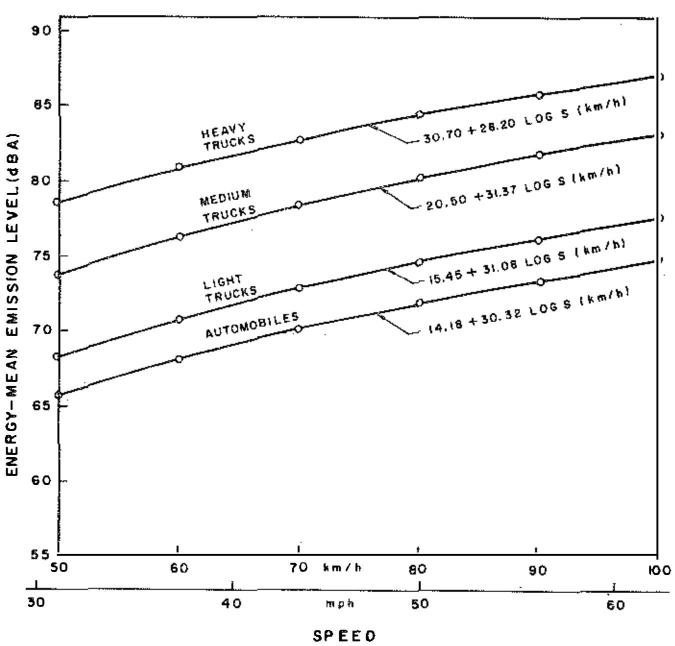

Figure 5. Reference mean energy emission levels for Kentucky Vehicles as a Function of Speed (Four Vehicle Categories).

An additional set of data was taken at several urban sites where automobiles dominated the noise level of the traffic stream. The speed limit at these locations varied from 35 mph (56.3 km/h) to 45 mph (72.4 km/h). Data were taken at 11 urban locations, and the results are summarized in Table 11. All data were taken 50 feet (15 m) from the centerline of the nearest traffic lane, and vehicles were classified into four categories. The SNAP 1 procedure with the revised emission levels for Kentucky slightly overpredicted the noise levels. The original SNAP 1 procedure gave better overall results considering both L10 and Leq. The average SNAP 1 predictions for Leq were very close to measured values.

COMPARISON OF NOISE LEVELS DURING PAST YEARS

Noise levels for individual vehicles have been measured on several occasions during the past several years on the interstate roads. A summary of data collected in 1973, 1974, and 1978 is given in Table 12. The data collection involved only the measurement of noise and not speed. The average speeds cited in the table were collected independently. The 1980 noise data were not included because speed data were taken at the same time as noise measurements and because the average speeds were lower. Observations using a concealed radar meter showed an average speed of slightly over 60 mph (96.5 km/h) compared to about 55 mph (88.5 km/h) for speeds taken with the noise data. The radar meter was not concealed when the

Table 11. Comparison of Measured and Predicted Noise Levels at Urban Locations (Average of 11 Sites).

	NOISE LEVEL (DBA)	
	L_{10}	L_{eq}
MEASURED	66.6	63.0
SNAP 1 PREDICTED	65.0	63.2
REVISED SNAP 1 PREDICTED (FOUR VEHICLE CATEGORIES)	67.9	65.3

Table 12. Change In Vehicle Noise Levels On Interstates For Several Years.

VEHICLE TYPE	1973* NUMBER OF VEHICLES	1973* AVERAGE NOISE LEVEL (DBA)	1974** NUMBER OF VEHICLES	1974** AVERAGE NOISE LEVEL (DBA)	1978*** NUMBER OF VEHICLES	1978*** AVERAGE NOISE LEVEL (DBA)
A	2000	77.4	578	75.2	665	73.6
SU2A6T	126	83.1	96	81.0	127	79.8
SU3A	15	85.4	20	86.0	21	82.2
C3A	18	86.4	25	86.2	12	85.2
C4A	83	88.4	58	86.7	57	83.1
C5A	257	90.6	248	88.9	352	86.1

* IN 1973, THE AVERAGE INTERSTATE SPEEDS WERE 68 MPH (109 KM/H) FOR CARS AND 63 MPH (101 KM/H) FOR TRUCKS.

** IN 1974, THE AVERAGE INTERSTATE SPEEDS WERE 59 MPH (95 KM/H) FOR BOTH CARS AND TRUCKS.

*** IN 1978, THE AVERAGE INTERSTATE SPEEDS WERE 62 MPH (100 KM/H) FOR CARS AND 61 MPH (98 KM/H) FOR TRUCKS.

noise data were taken. Inasmuch as the data shown in Table 12 were collected using identical procedures, they were comparable.

The data showed a decrease in noise level for both automobiles and trucks over the past several years. The decrease from 1973 to 1974 was probably related to the decrease in speeds as a result of lowering the speed limit from 70 mph (112.6 km/h) to 55 mph (88.5 km/h). However, there was also a decrease in noise levels from 1974 to 1978, during which time the speeds increased slightly. Part of the decrease in automobile noise levels could be related to a larger proportion of compact cars that are slightly quieter than full-size cars. The reduction in truck noise is probably related to the increased emphasis placed on the manufacture of quieter trucks.

Collection of individual vehicle noise levels on urban streets had not been done since the survey of 1973 (1). Data (using the identical procedure) were collected at four of the same locations in 35-mph (56.3-km/h) speed zones and compared to data collected in 1973. A total of 750 measurements of automobiles were taken. The data from each location were averaged and then an average of the four locations was calculated. The average noise level in 1980 was 66.9 dBA compared to 67.5 dBA in 1973. A very limited number of truck measurements were made. The 1973 data did not classify trucks by type, so there is only an overall average. However, virtually all 1980 data for trucks were for medium trucks. The average noise of trucks was 71.9 dBA in 1980 compared to 73.6 dBA in 1973. Therefore, there has been a slight reduction in individual vehicle noise levels at low-speed locations (35-mph (56.3-km/h) speed limit).

OCTAVE-BAND ANALYSIS

The octave-band noise levels emitted from automobiles, single-unit two-axle six-tire trucks, and combination five-axle trucks were determined. Data were taken on an interstate (average speed of 62 mph (99.8 km/h)) and on an urban arterial street (average speed of 38 mph (61.1 km/h)). About 100 automobiles were monitored for each frequency. A smaller number of trucks were sampled. There were very small samples of combination five-axle trucks for the urban arterial location.

The octave-band noise levels for the three vehicle types are given in Figures 6 and 7 for the interstate and urban arterial locations, respectively. At both locations, the spectrum did not vary significantly for the three vehicle types. The highest level for each type of vehicle was in the octave-band centered at 125 Hz, and the next highest levels were in the octave bands centered at 63 and 250 Hz.

The data were adjusted to reflect the frequency response of the A-scale filter as shown in Figures 8 and 9. The curves did not vary significantly between and among the vehicle types. The highest noise levels were in the octave-bands centered at 1,000 and 2,000 Hz. Also

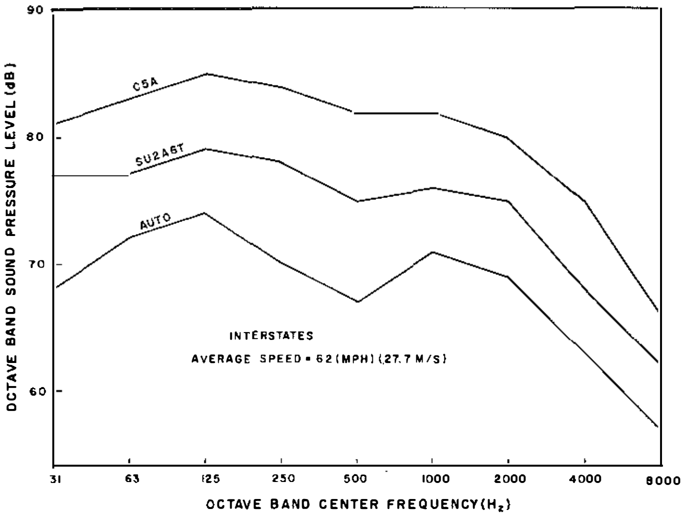

Figure 6. Octave-band sound pressure levels (interstate location).

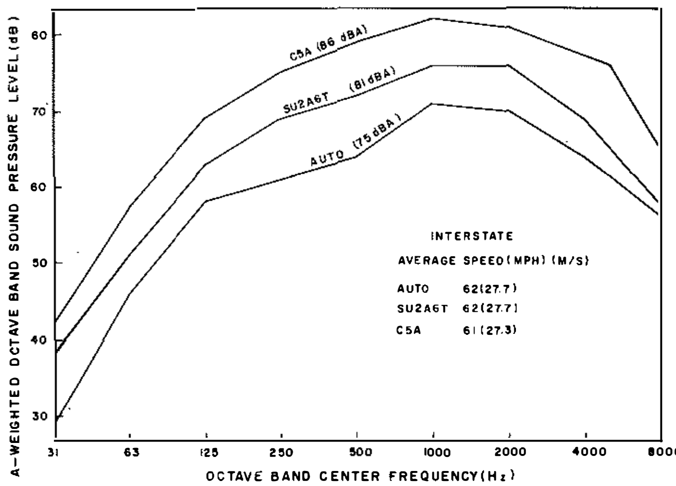

Figure 8. A-weighted octave-band sound pressure levels (interstate location).

given in the figures are the A-scale levels resulting from adding the individual A-weighted octave-band sound-pressure levels. At each site, there was a 5- to 6-dBA difference among vehicle types. A 7-dBA difference in the two locations was found for each vehicle type. The noise levels compared well with values from Figure 2 for the given speeds of each vehicle type.

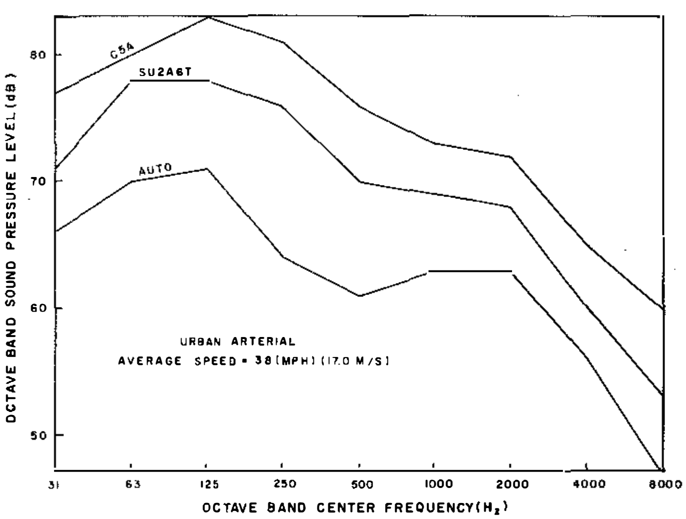

Figure 7. Octave-band sound pressure levels (urban arterial).

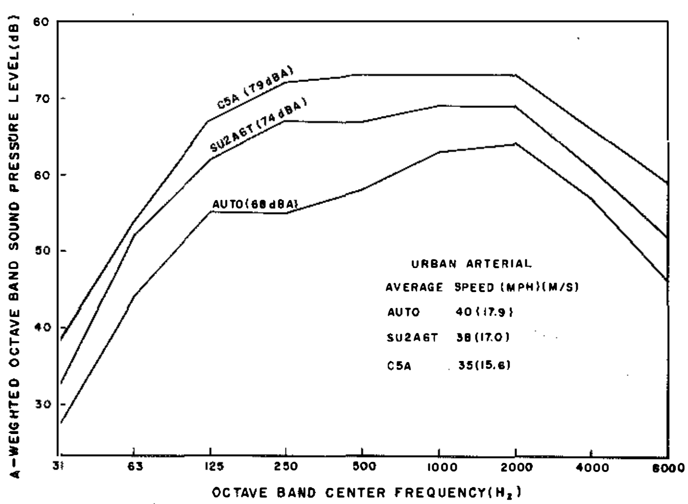

Figure 9. A-weighted octave-band sound pressure levels (urban arterial).

Summary

Comparison of mean energy emission levels of Kentucky vehicles with nationwide levels showed a close agreement for medium and heavy trucks; however, automobile emission levels in Kentucky were higher (up to 4 dBA at low speeds) than nationwide levels.

An analysis of the emission levels of the various types of vehicles showed that, except for motorcycles and single unit two-axle four-tire (SU2A4T) trucks, the vehicles generally belonged in three categories: automobiles, medium trucks, and heavy trucks. Motorcycles should be included in the medium truck category. A fourth category for SU2A4T trucks, termed light trucks, may be needed.

Substituting Kentucky mean energy emission levels for the nationwide levels currently used in SNAP 1 did not increase the accuracy of the SNAP 1 predictions. In fact, the nationwide emission levels resulted in closer agreement between measured and predicted values, particularly in urban locations where automobiles dominated the traffic stream.

Noise levels of individual automobiles and trucks have decreased over the past several years.

The shape of the frequency spectra for the three types of vehicles (A, SU2A6T, C5A) did not vary significantly. The unweighted frequency analysis showed the highest level at the octave-band centered at 125 Hz while the A-weighted frequency analysis showed highest levels in the octave-bands centered at 1,000 and 2,000 Hz.

Recommendations

It is recommended that the equations relating emission levels and speed for the four vehicle types (A, LT, MT, and HT) be adopted as representative of emission levels for Kentucky vehicles. These four vehicle types give the best representation of emission levels for Kentucky vehicles. The equations for these four types follow:

VEHICLE TYPE	EQUATION(SPEED IN km/h)
AUTOMOBILE (A)	14.18 + 30.32 log S
LIGHT TRUCKS (LT)	15.45 + 31.08 log S
MEDIUM TRUCKS (MT)	20.50 + 31.37 log S
HEAVY TRUCKS (HT)	30.70 + 28.20 log S

However, it is also recommended that the use of the nationwide emission levels be continued in the SNAP 1 program until such time as results showing better agreement between measured and predicted values using the nationwide levels can be explained.

The analysis yielded the following equations relating emission levels and speed for Kentucky vehicles for the three categories currently used in SNAP 1:

VEHICLE TYPE	EQUATION(SPEED IN km/h)
AUTOMOBILES (A)	14.69 + 30.43 log S
MEDIUM TRUCKS (MT)	20.50 + 31.37 log S
HEAVY TRUCKS (HT)	30.70 + 28.20 log S

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3. Kessler, F. M.; and Alexander, M.; "Sound Procedures for Measuring Highway Noise," U. S. Department of Transportation, Federal Highway Administration, Report No. FHWA-DP-45-1, May 1978.
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5. Rudder, F. F., Jr.; and Lam, D. F.; "User's Manual, FHWA Highway Traffic Noise Prediction Model SNAP 1.0," U. S. Department of Transportation, Federal Highway Administration, Report No. FHWA-RD-78-138, July 1978.
6. Ma, Y. Y.; and Rudder, F. F., Jr.; "Statistical Analysis of FHWA Traffic Noise Data," U. S. Department of Transportation, Federal Highway Administration, Report No. FHWA-RD-78-64, July 1978.

APPENDIX

SUMMARY OF DATA BY LOCATION

Table A-1. Summary of Data By Location.

LOCATION	NUMBER OF VEHICLES SAMPLED: AUTOMOBILES	MEDIUM TRUCKS	HEAVY TRUCKS	TOTAL*	SPEED LIMIT (MPH) (KM/H)
INTERSTATE 75	1016	132	750	1898	55 (88.5)
NEWTOWN PIKE (KY 922)	1061	100	267	1428	55 (88.5)
RICHMOND ROAD (US 25)	698	62	63	823	55 (88.5)
UNIVERSITY OF KENTUCKY-ROAD D	730	19	1	750	35 (56.3)
INTERSTATE 64	473	45	152	670	55 (88.5)
NANDINO BOULEVARD	462	72	74	608	35 (56.3)
LEESTOWN PIKE (US 421)	481	38	60	579	45 (72.4)
RICHMOND ROAD (URBAN) (US 25)	398	46	16	460	45 (72.4)
WINCHESTER ROAD (US 60)	338	56	41	435	55 (88.5)
NEW CIRCLE ROAD (KY 4)	320	55	45	420	45 (72.4)
EUCLID AVENUE (KY 1974)	357	20	4	381	35 (56.3)
HARRODSBURG ROAD (US 68)	283	33	22	338	55 (88.5)
NEWTOWN PIKE (KY 922)	276	26	4	306	50 (80.4)
COOPER DRIVE (KY 2333)	232	3	3	238	35 (56.3)
NEW CIRCLE ROAD (KY 4)	179	22	22	223	45 (72.4)
NICHOLASVILLE ROAD (US 27)(URBAN)	186	9	4	199	45 (72.4)
NICHOLASVILLE ROAD (US 27)	120	12	54	186	55 (88.5)

LOCATION	AVERAGE SPEED (MPH) (KM/H): AUTOMOBILES	MEDIUM TRUCKS	HEAVY TRUCKS	AVERAGE NOISE LEVEL (DBA): AUTOMOBILES	MEDIUM TRUCKS	HEAVY TRUCKS
INTERSTATE 75	55.2 (88.8)	52.6 (84.6)	54.1 (87.0)	74.6	80.2	84.2
NEWTOWN PIKE (KY 922)	46.3 (74.5)	39.1 (62.9)	42.8 (68.9)	70.8	75.9	81.5
RICHMOND ROAD (US 25)	50.2 (80.8)	46.9 (75.5)	47.3 (76.1)	73.5	78.7	83.5
UNIVERSITY OF KENTUCKY-ROAD D	30.3 (48.8)	26.0 (41.8)	28.3 (45.5)	61.6	67.4	66.0
INTERSTATE 64	55.5 (89.3)	54.2 (87.2)	53.2 (85.6)	73.2	79.8	83.6
NANDINO BOULEVARD	27.2 (43.8)	26.5 (42.6)	24.5 (39.4)	63.3	68.8	72.0
LEESTOWN PIKE (US 421)	51.1 (82.2)	48.2 (77.6)	49.5 (79.6)	69.4	76.1	81.1
RICHMOND ROAD (URBAN) (US 25)	40.7 (65.5)	38.1 (61.3)	38.2 (61.5)	66.5	73.4	76.8
WINCHESTER ROAD (US 60)	49.3 (79.3)	45.7 (73.5)	46.7 (75.1)	70.3	76.4	80.6
NEW CIRCLE ROAD (KY 4)	39.3 (63.2)	35.7 (57.4)	33.3 (53.6)	68.8	73.2	77.7
EUCLID AVENUE (KY 1974)	33.6 (54.1)	28.6 (46.0)	25.0 (40.2)	66.4	72.1	79.2
HARRODSBURG ROAD (US 68)	50.6 (81.4)	46.2 (74.3)	47.4 (76.3)	70.4	76.8	81.9
NEWTOWN PIKE (KY 922)	35.9 (57.8)	33.3 (53.6)	40.5 (65.2)	62.8	68.4	76.2
COOPER DRIVE (KY 2333)	29.9 (48.1)	25.3 (40.7)	31.7 (51.0)	67.4	76.0	72.7
NEW CIRCLE ROAD (KY 4)	26.9 (43.3)	26.8 (43.1)	25.8 (41.5)	66.2	72.2	75.2
NICHOLASVILLE ROAD (US 27)(URBAN)	27.6 (44.4)	29.8 (47.9)	30.2 (48.6)	63.7	69.3	74.8
NICHOLASVILLE ROAD (US 27)	49.3 (79.3)	46.5 (74.8)	45.1 (72.6)	73.9	81.8	83.9

* DOES NOT INCLUDE MOTORCYCLES. ALSO, A FEW VEHICLES DID NOT HAVE A SITE LISTED.